(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) Publication number: 0 206 811 A2

(12) EUROPEAN PATENT APPLICATION

(21) Application number: 86304880.7

(22) Date of filing: 24.06.86

(51) Int. Cl.[4]: H 05 B 6/64

(30) Priority: 25.06.85 CA 485142
15.05.86 CA 485142

(43) Date of publication of application: 30.12.86
Bulletin 86/52

(84) Designated Contracting States: AT BE CH DE FR GB IT LI LU NL SE

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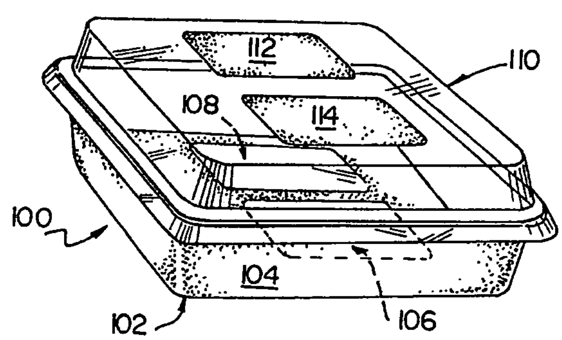
(54) Microwave container.

(57) A container for heating material in a microwave oven, said container comprising a metal, for example aluminium, foil tray (100) having a bottom (102) and sides (104). Bottom (102) is formed with two rectangular apertures (106) and (108). The container lid (110) is formed of microwave transparent material and has two metallic, for example aluminium, plates (112) and (114) located thereon. The plates (112) and (114) are located in registry with the apertures (106) and (108) respectively. Each of the apertures (106) and (108) and plates (112) and (114) are operable to generate a microwave field pattern having a higher order than that of the container, said field pattern propagating into the container to heat the material. This is achieved in the arrangement illustrated by amplifying the 2nd order mode within the container which has been found to give improved heat distribution within the material being heated. Several other alternative arrangements are possible, some of which are illustrated in the specification.



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Microwave container

The present invention relates to cooking containers which can be used in both a conventional oven and in a microwave oven. More particularly, the present invention relates to a container which, when used in a microwave oven, distributes the microwave energy more evenly throughout the foodstuff thereby reducing the hot and cold spot phenomenon currently being experienced in microwave cooking and also enables a particular desired heating distribution within the container to be achieved. Furthermore, some embodiments of the container of the present invention can be used in a conventional oven and its unique structure helps eliminate the problem of damage to the bottom of the combination microwave container when that container is of the dielectric plastic type.

According to the invention there is provided a container for containing a material to be heated in a microwave oven, said container comprising an open topped tray for carrying said material and a lid covering said tray to form a closed cavity, said container being characterised in that at least one surface of the container is formed with means for generating a microwave field pattern having a higher order than that of the fundamental mode of the container, said microwave generating means being so dimensioned and positioned with respect to the material when in the container that the field pattern so formed propagates into the

material to thereby locally heat the material. In a multi-compartment container, such as is used for heating several different foodstuffs simultaneously, the term "container" as used herein should be interpreted as meaning an individual compartment of that container. If, as is commonly the case, a single lid covers all compartments, then "lid" as used above means that portion of the lid which covers the compartment in question.

The container may be made primarily from metallic material, such as aluminium, or primarily from non-metallic material such as one of the various dielectric plastic materials currently being used to fabricate microwave containers, or a combination of both.

In a conventional microwave oven, microwave energy, commonly at a frequency of 2.45 GHz, enters the oven cavity and sets up a standing wave pattern in the cavity, this pattern being at fundamental modes dictated by the size and shape of the walls of the oven cavity. In an ideal cavity only the fundamental mode exists, but in practice due to imperfections in the shape of the side walls, small protrusions, and steps, which inevitably exist in the oven cavity, higher order modes are also generated within the cavity and are superimposed on top of the fundamental mode. Generally speaking these higher order modes are very weak and in order to promote better distribution of energy within the container a "mode stirrer" can be used to deliberately generate or enhance the higher order modes.

If a container, such as a food container, is placed into the microwave oven, and microwave energy is caused to propagate into the interior of that container then a similar situation exists within the container as exists within the oven itself: a standing wave pattern is set up within the container, this pattern being primarily in the fundamental modes of the container (as distinct from the fundamental modes of the larger oven cavity), but also containing modes higher than that of the fundamental modes of the container, which higher modes are generated due to irregularities in the interior shape of the container and its contents.

As before, these higher order modes are generally of much lower power than the fundamental and contribute little to the heating of the material within the container.

Attention will now be directed to the manner in which the material within the container is heated by the microwave energy existing within the container. In doing this, it is convenient to study only horizontal planes within the container. It is well known that the standing wave pattern within the container consists of a combined electric and magnetic field. However the heating effect is obtained only from the electric field and it is therefore of significance to look at the power distribution of the electric field as it exists under steady state conditions within the container. In the fundamental mode - which it should be recalled is the primary one existing within the container - the pattern of power distribution in the horizontal plane is confined to the edge of the container and this translates into a heating effect which is likewise concentrated around the edge of the container. The material in the central part of the container receives the least energy and therefore, during heating, the centre tends to be cool. In conventional containers, this problem of uneven heating is solved by instructing the user to leave the material unattended for a few minutes after the normal microwave cooking time in order for normal thermal conduction within the food to redistribute the heat evenly. Alternatively, the material may be stirred, if it is of a type which is susceptible to such treatment.

The shape of these "cold" areas varies according to the shape of the container. For example, for a rectangular container the shape of the cold area in the horizontal plane is roughly rectangular with rounded corners; for a container which is circular in horizontal cross section, the cold area will be likewise circular and postioned at the centre of the container. For irregular shaped container, such as is commonly found in compartments of a multi-compartment container, the "cold" area will roughly correspond to the outside contour of the container shape and will be positioned centrally of the container.

In considering the heating effect of higher modes which may or may not exist within the container, it is necessary to notionally subdivide the container into cells, the number and arrangement of these cells depending upon the particular higher order mode under consideration. Each of these cells behaves, from the point of view of microwave power distribution as if it were itself a container and therefore exhibits a power distribution which is high around the edges of the cell, but low in the centre. Because of the physically small size of these cells, heat exchange between adjacent cells during cooking is improved and more even heating of the material results. However in the normal container, i.e. unmodified by the present invention, these higher order modes are either not present at all or, if they are present, are not of sufficient strength to significantly heat the food. Thus the primary heating effect is due to the fundamental mode of the container - i.e. a central cold area.

Recognizing these problems, what the present invention seeks to do, in essence, is to heat this cold area by introducing heating energy into the cold area. This can be achieved in two ways:

1) by redistributing the microwave field pattern within the container by enhancing higher order modes which naturally exist anyway within the container due to the boundary conditions set by the physical geometry of the container, but not at an energy level sufficient to have a substantial heating effect or, where such naturally higher order modes do not exist at all (due to the geometry of the container), to generate such natural modes.

2) to superimpose or "force" onto the normal field pattern - which, as has been said, is primarily in the fundamental mode - a further higher order field pattern whose characteristics owe nothing to the geometry of the container and whose energy is directed towards the geometric centre of the container in the horizontal plane which is the area where the heating needs to be enhanced.

In both the above cases the net result is the same: the container can be notionally considered as having been split into several smaller areas each of which has a heating pattern similar to that of the fundamental mode, as described above. However, because the areas are now physically smaller, normal thermal convection currents within the food have sufficient time, during the relatively short microwave cooking period, to evenly redistribute the heat and thus avoid cold areas. In practice, under certain conditions higher order mode heating may take place due to both of the above mechanisms simultaneously.

The process for generating the microwave field may take one of two forms:

1) where said at least one surface of the container takes the form of a sheet of microwave transparent material, a plate of electrically conductive material which is attached to or forms part of the sheet. Such a plate could be made for example of aluminum foil which is adhered to the sheet, or could be formed as a layer of metallisation applied to the sheet.

2) Where said at least one surface of the container takes the form of a sheet of electrically conductive material, such as aluminium foil, an aperture in the sheet through which microwave energy incident on the sheet can pass. Preferably, the aperture is covered by microwave transparent material.

It will be appreciated that the two alternatives listed above - i.e. the plate and the aperture - are simply analogues of one another and both in fact operate in exactly the same way. For ease of understanding, in the first alternative, the plate can be considered as a two - dimensional antenna where characteristics can be calculated from well-known antenna theory. Thus, the plate can be considered as receiving microwave energy from the oven cavity, whereupon a microwave field pattern is set up in the plate, the characteristics of which pattern are dictated by the size and shape of the plate. The plate then retransmits this energy into the interior of the container as a microwave field

pattern. Because the dimensions of the plate are necessarily smaller than that of the container surface with which it is associated, the order of the mode so transmitted into the interior will be higher than the container fundamental mode.

In the second alternative, the aperture can be considered as a slot antenna whose characteristics can once again be calculated from theory. The slot antenna so formed effectively acts as a window for microwave energy from the oven cavity. The edges of the window define a particular set of boundary conditions which dictate the microwave field pattern which is formed at the aperture and transmitted into the interior of the container. Once again, because the dimensions of the aperture are smaller than that of the container surface with which it is associated, the shape and (particularly) the dimension of the aperture are such as to generate a mode which is of a higher order than the container fundamental mode.

Several separate higher order mode generating means - be they plates or apertures - may be provided on each container to improve the heat distribution. The higher order mode generating means may all be provided on one surface of the container, or they may be distributed about the container on different surfaces. The exact configuration will depend upon the shape and normal (i.e. unmodified by the present invention) heating characteristics, the object always being to get microwave energy into the cold areas, thus electrically subdividing the container down into physically smaller units which can more readily exchange heat by thermal conduction. The considerations which are to be given to the positioning of the higher order mode generating means will depend upon which of the two mechanism of operation it is desired to use: If it is desired to enhance or generate a particular higher order mode which is natural to the container then the above mentioned cell pattern appropriate to that mode should be used to position the plates or apertures forming the higher order mode generating means. Basically in order to enhance or generate a natural mode,

a plate/aperture of approximately the same size as the cell will need to be placed over at least some of the cells - the larger the number of cells which have a plate or aperture associated with them, the better the particular mode chosen will be enhanced. In practice a sufficient space must be left between individual plates/apertures in order to prevent field interaction between them - it is important that each plate/aperture is sufficiently far from its neighbour to be able to act independently. If the spacing is too close, the incident microwave field will simply see the plates/apertures as being continuous and, in these circumstances, the fundamental mode will predominate, which will give, once again, poor heat distribution. A typical minimum spacing would be in the region of 3 to 4 mm. The average spacing is usually in the range 6 to 12 mm, depending upon the particular container geometry and size.

If, on the other hand, it is desired to use the mechanism of "forcing" an unnatural higher order mode into the container, than the plate/aperture forming the higher mode generating means needs to be placed over the cold area or areas within the container. In such circumstances, the plate/aperture, in effect, acts as a local heating means and does not (usually) significantly affect the natural modes of the container. Thus the "forced" mechanism utilizes the heating effect of the container fundamental superimposed onto its own heating effect. At certain critical sizes and positioning of plates, both mechanisms - forced and natural - may come into play.

We have found it convenient to consider matters only in the horizontal plane and for this reason, the only surfaces which are formed with the higher order generating means in the embodiments which follow are horizontal surfaces - i.e. the bottom of the container or the lid of the container. However, there is no reason why the teachings of this invention should not be applied to other than horizontal surfaces since the ambient microwave field in which the container is situated is homogeneous.

Because the characteristics of the plate/aperture alternatives are so similar (indeed a particular aperture will transmit an identical mode to that transmitted by a plate of identical size and shape), it is possible to use them interchangeably - in other words, whether a plate or aperture of particular dimensions is used, can be dictated by considerations other than that of generating a particular microwave field pattern.

Clearly the heating effect of the higher order mode generating means will be greatest in the food immediately adjacent to it and will decrease in the vertical direction. Thus, it may be an advantage to provide higher mode generating means both in the lid and in the bottom of the container. Since the cold areas will be in the same position in the horizontal plane whether the lid or the bottom of the container are being considered, it is clearly convenient to make the higher mode generating means in the lid in registry with those in the bottom of the container. By this means, better heat distribution in the vertical direction can be achieved. It matters not which particular type of higher mode generating mean is used as between the lid and the bottom - in one embodiment, for example, a plate or plates are formed on the lid, while in-registry aperture or apertures are formed in the container bottom. In another embodiment, apertures are provided in both lid and bottom surfaces.

In order that the invention may be better understood. several embodiments thereof will now be described by way of example only and with reference to the accompanying drawings in which:-

Figures 1 to 4 are diagrammatic plan views showing four different patterns of the lid or bottom surfaces of a container constructed in accordance with the present invention:

Figure 5 is a graph showing, in an embodiment in which the higher mode generating means comprises a metal plate in the lid surface, the variation of heating energy entering the container as the area of the plate with respect to that of the whole lid is varied;

Figure 6 is an exploded perspective view of a container constructed in accordance with the invention;

Figure 7 is a view similar to that of Figure 6, showing a multi-compartment container;

Figures 8 and 9 are further views similar to Figure 6, showing further alternative embodiments; and

Figure 10 is a diagrammatic plan view of the container bottom surface (Figure 10A) and top surface (Figure 10B) of a still further embodiment of the invention.

Referring to Figure 1, the circular surface shown may comprise the bottom surface or the lid surface of circular cylindrical container 8. The surface, shown under reference 10, is made principally from microwave transparent material and is substantially planar (although this is not essential). The remainder of the container 8, which is not shown, may be of metal, such as aluminium foil, or one of the microwave transparent plastics material currently available. Attached to the surface are three similar segmental plates 12 of metal foil.

Each of the plates 12 acts as a source of a higher order mode wave pattern which propagates into the container and acts to generate a higher order mode harmonically related to the fundamental modes of the container and defined, in essence by the boundary conditions of the cylindrical wall of the container. The area 14 bounded by the three plates 12 is of microwave transparent material and is thus a route by which microwave energy enters the container.

Figure 2 is a similar to Figure 1, except that the plates. now shown under reference 16, are substantially semi-circular in plan view and are separated by a gap 18. This embodiment operates in the same way as the Figure 1 embodiment in that it generates a higher order mode harmonically related to the fundamental of the container and defined by the boundary conditions of the container. The difference between Figures 1 and 2 is simply in the order of the particular higher order mode generated: in Figure 1 a third order mode is being generated: in Figure 2 a second order mode.

Figures 3 and 4 each show a container bottom or lid surface 10 for a rectangular container 8. The two embodiments are the inverse of one another, but actually operate in an identical manner. In Figure 3, the surface 10 is made of conducting material such as metal in which are formed two rectangular apertures 22 covered with microwave transparent material. As explained above, each aperture 22 acts as a window, allowing through it microwave energy from the oven cavity. The shape and dimensions of the edge of the aperture create boundary conditions which establish a microwave field pattern which propagates into the container. The wave thus transmitted into the container is of a higher order than that of the container fundamental and acts to accentuate or amplify a higher (second) order mode - the E_{12} or E_{21} mode - which is almost certainly already present within the container but at a low power level. Once again this mode is harmonically related to that of the container fundamental and is therefore essentially determined by the geometry of the container. The amplification of the second order mode effectively electrically splits the rectangular dish into two identical cells divided roughly by the dividing line 24 between the two apertures 22. Each of these cells can, as explained above, be considered as a notionally separate container operating in the fundamental mode. Thus, although a relatively cool area is found at the centre of each of the notionally separate containers, because the containers are physically only half the size of the actual container. the problem of redistributing heat by thermal conduction from the hotter areas into the cooler areas, is greatly reduced.

It will be seen that generating still higher modes and thereby electrically subdividing the container into a larger number of smaller and smaller cells will result in this problem of conductive exchange of heat being still further reduced, but this process cannot be carried out to an unlimited extent. The reason for this is that the higher the mode order, the more quickly it attenuates after having left the aperture 22 from which it was generated. The same applies to retransmission from metal plates.

Thus there comes a stage, particularly when an air gap exists between the food and the surface 10, where the microwave energy may not even reach the surface of the food, or may only just reach it. Thus it is important that the order of mode generated is sufficiently low not to be attenuated too rapidly within the food being heated; otherwise, the heating effect of the higher order mode will be negligible and the heating characteristics will be those of the container fundamental.

We have found that the lower the order of the mode - i.e. the nearer the fundamental - the less pronounced is the attenuation in the air gap (if any) between the surface 10 and the food and the less abrupt the absorption within the food. An abrupt absorption profile within the food will give a concentration of energy, and hence heating, near the food surface which in turn results in browning or crispening of the food.

Thus, unless there is a specific requirement for browning or crispening, the preferred higher order mode is that which is as low as possible, consistent with giving an acceptable distribution of heating within the food. The exact value of the order which is decided on will also depend upon the physical size of the container in the horizontal plane - clearly large containers will have to be operated in higher modes in order to keep down the physical size of each heating cell. However it has been found that, under most curcumstances, container modes between the first order and the fifth order (the fundamental being regarded as the zeroth order) will be used.

A further constraint on the dimensions of the plate or aperture which forms the higher order mode generating means is connected with the single dimensional resonance of the plate or aperture at the operating frequency of the oven (usually 2.45 GHz). Drawing on the above-mentioned analogy with two-dimensional antennae, it will be apparent that at a certain size the plate/aperture will resonate. As it happens the expected size for resonance is affected by the fact that the antenna - i.e. the plate or aperture - does not exist in free space, but rather is affected by the nearby presence of lossy material - in particular the material (usually food) being heated. The presence of the food distorts the radiation pattern of the antenna and causes resonance to occur at dimensions different from those which would be predicted by free space calculations. It is desirable to keep the linear dimensions (length and width) away from those values causing resonance and sub-multiples of those values. The reason for this is that, at resonance, the antenna generates high field potentials which are capable of causing electrical breakdown and overheating in adjacent structures. Also, the antenna radiates strongly in the direction of the food, and can cause burning before the remainder of the food is properly cooked.

Turning now particularly to Figure 4, the higher order mode generating means is now formed of a pair of plates 26. These act in the same way as the windows of 22 of the Figure 3 embodiment, and will amplify the E_{12} or E_{21} mode already in the container.

The following are actual examples of test results carried out on circular and rectangular metal foil containers. In each

instance the plates comprised metal foils attached to thermoformed 7 mil polycarbonate lids. The test oven was a 700 watt Sanyo (trade mark) microwave oven set at maximum power. A thermal imager was an ICSD model No. 320 thermal imaging system and video interface manufactured by ICSD (trade mark) Corporation. The load to be heated was water saturated into a cellular foam material.

Using a 190 gram water load, without the cellular material, an unmodified 12.7 cm diameter foil container was tested. After 60 seconds an average temperature rise of 13°C was observed. A 6 cm diameter foil disk was then centrally located on the lid and the test repeated. The temperature rise was determined to be 15.5°C. A 1.5 cm aperture was made in the 6 cm foil disk, approximating the configuration shown in Fig. 1 and a 17.5°C temperature rise was observed.

Using the cellular foam material containing a 175.5 gram water load, the test container was heated for 40 seconds and its thermal images recorded. Heating was concentrated around the edge of the load with a temperature differential of about 10°C between the edge and the center of the container. With a 6 cm foil disk on the cover as described above, the thermal images indicated heating both at the center and edge of the container, showing a better thermal distribution. With the 1.5 cm diameter aperture a slightly more even thermal image was obtained for a 40 second test.

Tests using actual foodstuff showed that the disk and disk-aperture configuration browned the upper surface of the foodstuff.

A 17x12.7 cm rectangular foil container was then tested. A 390 gram water load was raised 10.5°C in 60 seconds. Two transversely positioned foil rectangles were mounted on a cover, approximating Fig.4. The following table shows the results:

Rectangle size of ground planes	Temperature Rise C°
10.5x6.8 cm	11.5
9.5x6.3	13.5
8.5x5.3	13.5
7.5x4.3	13.0
6.5x3.3	12.0
5.5x2.3	12.0

Thermal imaging results for the smaller structures showed regions of most intense heating which appear to correspond in shape to the metal plates. The use of the dual rectangular shape of Figure 4 clearly improves the uniformity of heating of the foodstuff. Once again, using an actual foodstuff the top surface of the foodstuff was browned.

Reference will now be made to Figures 5 and 6 which relate to an embodiment in which the container comprises a generally rectangular metal foil tray 40 having a lid 42 of microwave transparent material located thereon. A skirt 44 elevates the top surface 46 of the lid above the top of the tray 40 and therefore above the top surface of the foodstuff contained within the container. A plate 48 of conducting material is centrally located on the top surface 46 of the lid 42. The plate 48 has a shape approximately corresponding to the shape of the top surface 46 of the lid, although strict conformity of shape is not essential. The arrangement shown in Figure 6 can be used to illustrate a number of the features of the invention.

Using the Figure 6 arrangement, the size of the plate 48 was varied in relation to the size of the surface 46 and the results plotted graphically (Figure 5). In Figure 5 the Y-axis represents the amount of microwave energy entering the container from the oven cavity, with an unmodified lid (i.e. no plate 48 present) shown as a datum. The X-axis represents the ratio of the area of surface 46 to that of plate 48. The size of plate 48 was reduced

in steps by increasing the width of the microwave-transparent border area by equal amounts. When the size ratio is 100%, the energy entering the container is substantially zero because energy can only enter via the skirt 44 and is greatly limited. As the size of area 48 is reduced, a high peak is produced at a particular size, which is the size at which the beating effect of the fundamental mode of the container superimposes most favourably on that of the plate 48. Note that the heating effect of this is still very akin to that of the container above, only stronger, because of the superposition of the fundamental mode of the plate - there is still a significant cool area in the centre.

As the size of plate 48 is reduced further the effect of the higher order mode generated by the plate becomes more distinct from that of the container fundamental and thus more significant. The most favourable area is reckoned to be a ratio of between 40% and 20%. Below 20% the order of the mode generated by the plate becomes very high and the wave transmitted from the plate is, as explained above, attenuated so quickly in the vertical direction as to have little effect on the overall heating characteristic, which thus return to being that of the fundamental mode within the container.

In fact, at most sizes, the plate 48 of the Figure 6 embodiment operates by a different mechanism to that of each of the areas, be they plates or apertures, in the embodiments of Figures 1 to 4. Instead of generating or amplifying a higher order mode which the container would naturally posses due to the boundary conditions set by its physical characteristics, as in the embodiments of Figures 1 to 4, the plate 48 of Figure 6 "forces" into the container a mode in which the container, due to its physical characteristics, would not normally operate. The mode in this case is dictated solely by the size and shape of the plate 48 which in essence sets up its own fundamental mode within the container.

Of course, the fundamental mode of the plate 48 is necessarily of a higher order than that of the container itself, because the plate 48 is physically smaller than the container. This fundamental mode (of the plate 48) propagates into the interior of the container and has a heating effect on the adjacent food. Note that the central location of the plate 48 causes this heating effect to be applied to that part of the container which, when operating simply in the fundamental mode of the container, would be a cool area. Thus in this case the object is not, as in Figures 1 to 4, to accentuate the higher modes at the expense of the fundamental of the container, but rather to give a uniform heating by utilizing the fundamental mode of the plate 48 in conjunction with the fundamental mode of the container. No attempt is made to generate or amplify naturally higher order modes of the container. However it is likely that, in some circumstances both mechanisms will operate together to provide an even distribution of microwave power within the container.

At one particular size of plate 48 the mechanism which utilizes amplification of naturally higher order modes of the container becomes predominant. If we notionally divide the rectangular top surface 46 into a 3x3 array of equal size and shape (as far as is possible) rectangles, then a plate 48 positioned over the central one of these, having an area of approximately one ninth of the area of surface 46 will have a size and shape such that it will generate a third order mode (E_{33}) with respect to the fundamental of the container. This is a mode which may well be naturally present within the container, but at a very low power level. The power distribution pattern of the mode in the horizontal plane comprises a series of nine roughly rectangular areas corresponding to each of the nine areas notionally mapped out above. The presence of a single plate 48 of a size and shape corresponding to the central one of these areas will encourage the presence of this natural higher order mode within the container and will indeed give a very even distribution of heating. A further (and better) method of generating this same mode is described below.

Figure 6 shows a multi-compartment container 40 in which each compartment is treated separately in accordance with the teachings of this invention. The container has a series of metallic walls (not shown) which form compartments directly under regions 50, 52, 54 and 56 in a lid 58. The lid is made of a microwave dielectric material and is basically transparent to microwave energy. Each compartment has a corresponding top surface area in lid 58 and each top surface area has an approximately conformal plate of metallic foil. Such conformal plates are shown in Figure 7 at 60, 62, 64 and 66. The area of each conformal plate is dimensioned so as to provide the proper cooking energy and distribution to the foodstuff located in the compartment in question. For example, conformal plate 60 is large with respect to this compartment and shields the foodstuff located in region 50. The foodstuff in that compartment does not need much heating and distribution is not a consideration. On the other hand, the foodstuff in region 56 requires an even distribution of heating and so conformal plate 66 is appropriately dimensioned.

Referring to Figure 8, there is shown a can type cylindrical container 80 which has metallic side walls 82 and a metallic lid 84 and a metallic bottom 86. The container can be made from any metallic material such as aluminum or steel.

Circular aperture 88 which is coaxial with the circular bottom 86 is centrally located in bottom 86. The aperture 88 is covered with a microwave-transparent material 90. A similar aperture 92 and microwave-transparent covering 94 is located on the lid 84. The apertures 88 and 92 will be seen to act as windows to a particular higher mode of microwave energy, the order of this particular mode being dictated by the diameter of the apertures. Because the apertures are located top and bottom, the vertical heat distribution is improved, as explained above. The vertical height "h" of the container can be large and still result in good heating of the foodstuff. Here again, the diameter of each of the apertures in relation to that of the adjacent top or bottom surface dictates the mechanism of operation - i.e. whether

natural container modes are generated or enhanced, or whether a "forced" mode, dictated solely by the characteristics of the aperture 88 or 92 is forced into the container to heat, in conjunction with the heating effect of the container fundamental.

Figure 9 is a further embodiment in which higher mode generating sources are located both in the lid and in the bottom of the container for better vertical heat distribution. The container consists of a metal foil tray 100 having a bottom 102 and sides 104. Bottom 102 includes two rectangular apertures 106 and 108. The container also includes a microwave-transparent lid 110 which has two metallic plates 112 and 114 located thereon. The plates 112 and 114 are located in registry with apertures 108 and 106, respectively. This embodiment operates essentially in the same manner as Figures 3 and 4 above and further explanation is thus omitted.

Figures 10A and 10B are plan views of, respectively, the container bottom 120 and lid 140 of a further embodiment. From the microwave point of view, it will be understood that the lid and bottom could in fact be interchanged as between Figures 10A and 10B.

In Figure 10A, the bottom is shown as being primarily metallic which is obviously convenient if the rest of the container tray is metallic. The bottom is formed with a 3x3 array of nine apertures 122 to 138, each of which is covered with microwave transparent material. The lid 140 is primarily of microwave transparent material and is formed on its surface with a 3x3 array of nine plates 142 to 158 of conductive material such as metal. It will be seen from the pattern of plates apertures in this embodiment that the mechanism of operation is by way of amplification of the third order (E_{33}) mode. In fact presence of any one or more of the nine plates/apertures in the appropriate position will enhance the mode, as has already been seen above in the discussion of a single centrally-located plate, but the presence of all nine plates will provide still greater enhancement of this mode and thus particularly even heating. Figures 10A and

10B also illustrate the "tailoring" of the plate sizes to improve heat input to particularly cold areas; in this invention it will be noted that the size of the central aperture 130/plate '50 is slightly greater than that of the remainder. The result of this is to cause the central plate aperture, overlying the coldest central area of the container to operate not only to encourage amplification of the third order mode of the container, but also to act by the "forcing" mechanism by imposing its own field pattern on the central area. Such tailoring and shaping of particular areas is particularly useful for irregularly shaped containers or, as here, to enhance the heat input to particularly cold areas.

Typical dimensions for the embodiment of Figure 10 are as follows:-

container overall width	= 115 mm
container overall length	= 155 mm
container overall depth	= 30 mm
length of central aperture 130/plate 150	= 41 mm
width of central aperture 130/plate 150	= 27 mm
length of remaining aperture/plates	= 35 mm
width of remaining apertures/plates	= 22 mm

The distance between adjacent apertures/plates is 11 mm, except for the central aperture/plate which is 9 mm.

While Figures 10A and 10B have been described as showing, respectively, a container bottom and lid for use together, it will be appreciated that either could be used alone. Thus, for example, the lid 140 of Figure 10B could be used with a metallic container wherein the bottom has no apertures, or with a container of a dielectric plastic material.

Various other shapes of metal plate can be used to generate higher modes. For example a ring-shaped plate of metal on a microwave transparent surface will result in the generation of two higher-order modes, one due to the exterior perimeter of the plate, and one still higher mode due to the interior perimeter of the plate. It is even possible to conceive a whole series of coaxial rings each one smaller than the last, and each generating two modes. Such ring-shaped plates could be circular, or could be

rectangular or square.

Other shapes and configurations of plate/aperture will be apparent to those skilled in the art.

CLAIMS

1. A container for containing a material to be heated in a microwave oven, said container comprising an open topped tray for carrying said material and a lid covering said tray to form a closed cavity, said container being characterised in that at least one surface of the container is formed with means for generating a microwave field pattern having a higher order than that of the fundamental mode of the container, said microwave generating means being so dimensioned and positioned with respect to the material when in the container that the field pattern so formed propagates into the material to thereby locally heat the material.

2. A container as claimed in claim 1 wherein said one surface is formed of a sheet of microwave transparent material and wherein the higher order mode generating means comprises at least one plate made of electrically conductive material, said plate being attached to said sheet.

3. A container as claimed in claim 1 wherein said one surface is formed of a sheet of electrically conductive material and wherein the higher order mode generating means comprises at least one aperture in the sheet.

4. A container as claimed in claim 3 wherein said or each aperture is covered with microwave transparent material.

5. A container as claimed in claims 2 and 3 or 4 wherein more than one said surface of the container is formed with a higher order mode generating means and wherein a first of said surfaces is formed of a

sheet of microwave transparent material to which is attached at least one plate as aforesaid, and wherein a second of said surfaces is formed of a sheet of electrically conductive material, in which sheet is formed at least one aperture as aforesaid.

6. A container as claimed in any one of claims 2 to 5 wherein the dimensions of said or each aperture or plate are such as to be non-resonant at the microwave frequency being used.

7. A container as claimed in any one of the preceding claims wherein the or each higher order mode generating means is so configured and positioned on its surface as to generate or amplify higher order modes which are natural to the container and dictated by its boundary conditions.

8. A container as claimed in any one of claims 1 to 6 wherein the or each higher order mode generating means is so configured and positioned on its surface as to generate a mode of higher order than that of the fundamental of the container but is not otherwise dictated by the boundary conditions of the container and would not normally exist therein.

9. A container as claimed in any one of the preceding claims comprising at least two higher order mode generating means each formed on a respective horizontal surface of the container, and wherein said means are in vertical registry with one another to thereby improve the vertical distribution of heating energy within the material.

10. A method of manufacturing a container for containing a material to be heated in a microwave oven, said container being of a type comprising an open-topped tray for carrying said material and a lid covering said tray to form a closed cavity, said method comprising forming on at least one surface of the container means for generating a microwave field pattern having a higher order than that of the fundamental mode of the container, said microwave generating means being so dimensioned and positioned with respect to the material when in the container that the field pattern so formed propagates into the material to thereby locally heat the material.

11. A method as claimed in claim 10 wherein the or each higher order mode generating means is so configured and positioned on its surface as to generate or amplify higher order modes which are natural to the container and dictated by its boundary conditions.

12. A method as claimed in claim 10 wherein the or each higher order mode generating means is so configured and positioned on its surface as to generate a mode of higher order than that of the fundamental of the container but is not otherwise dictated by the boundary conditions of the container and would not normally exist therein.

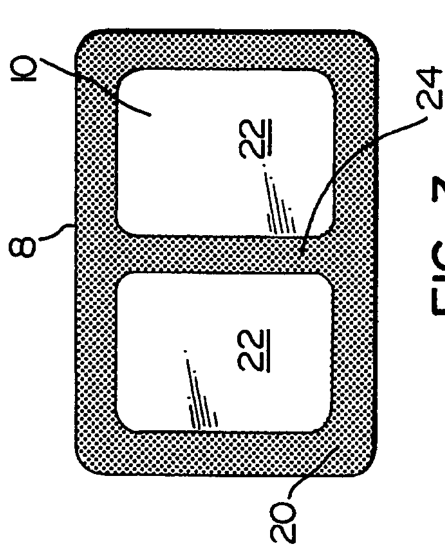

FIG. 3

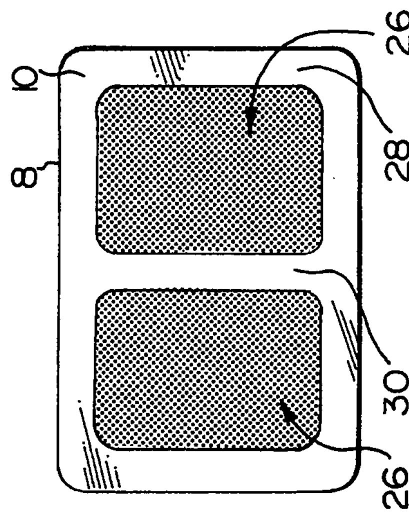

FIG. 4

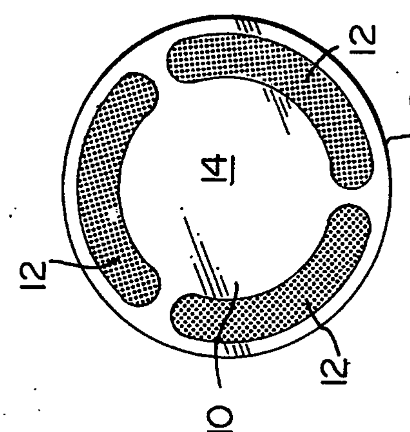

FIG.1

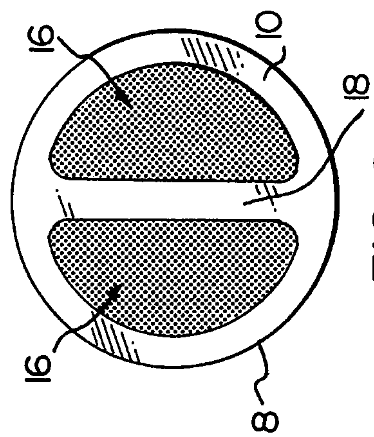

FIG. 2

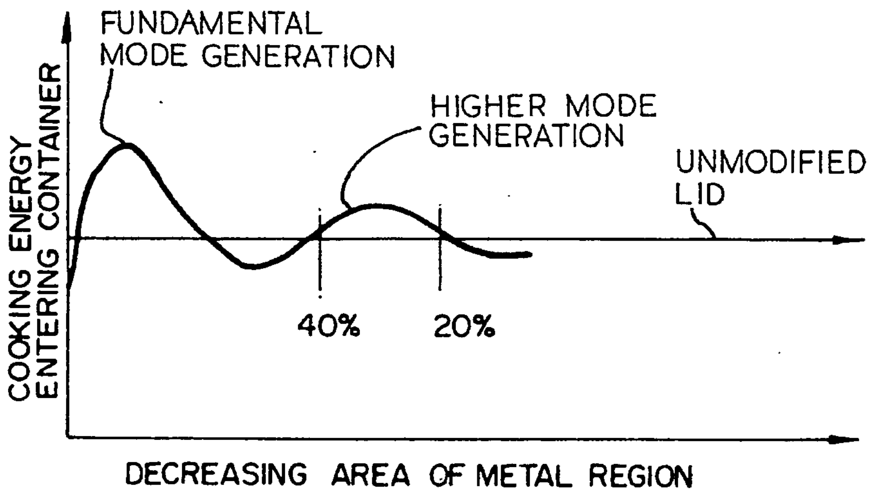

FIG.5

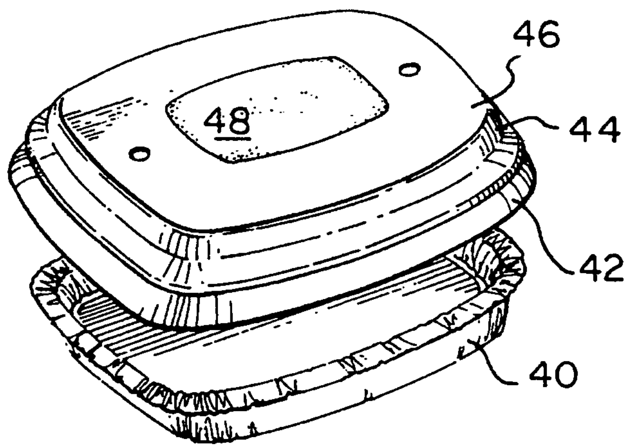

FIG.6

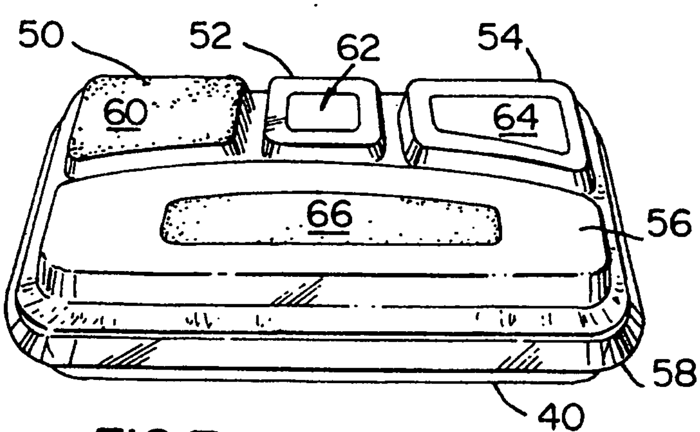

FIG.7

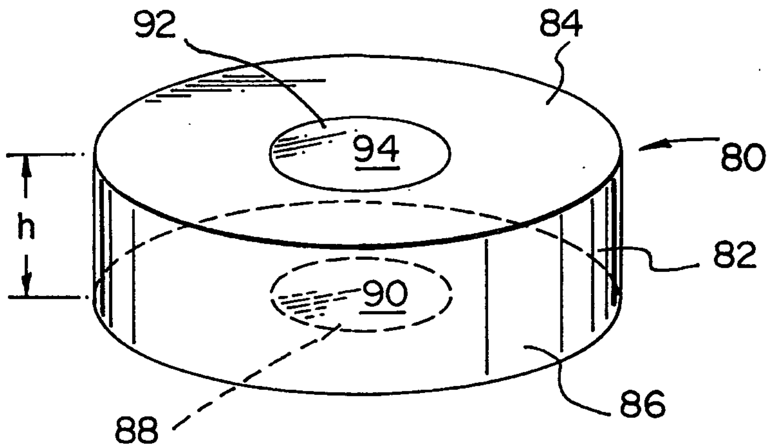

FIG.8

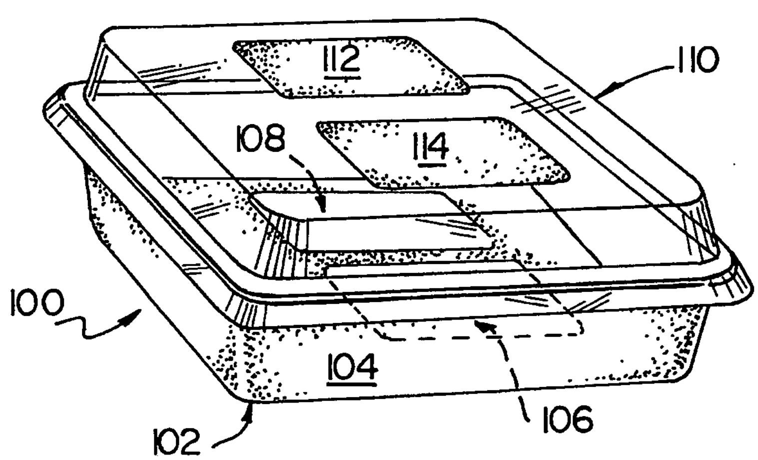

FIG. 9

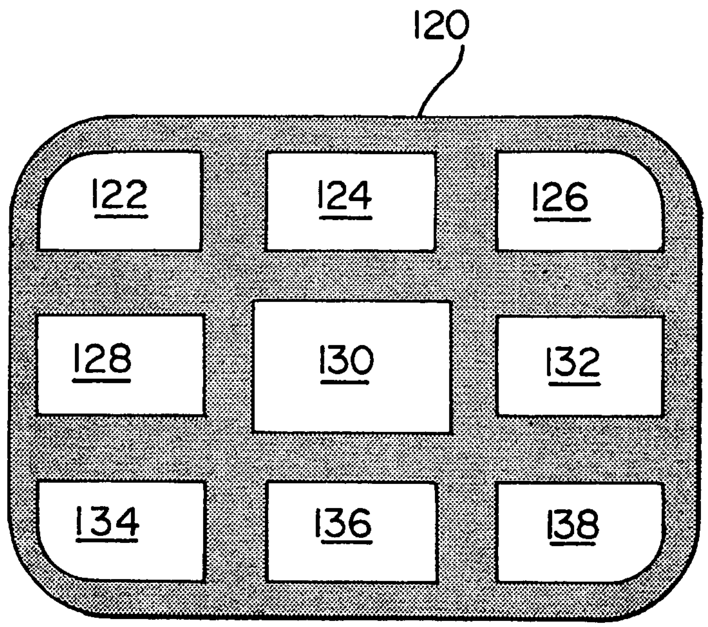

FIG. 10 A

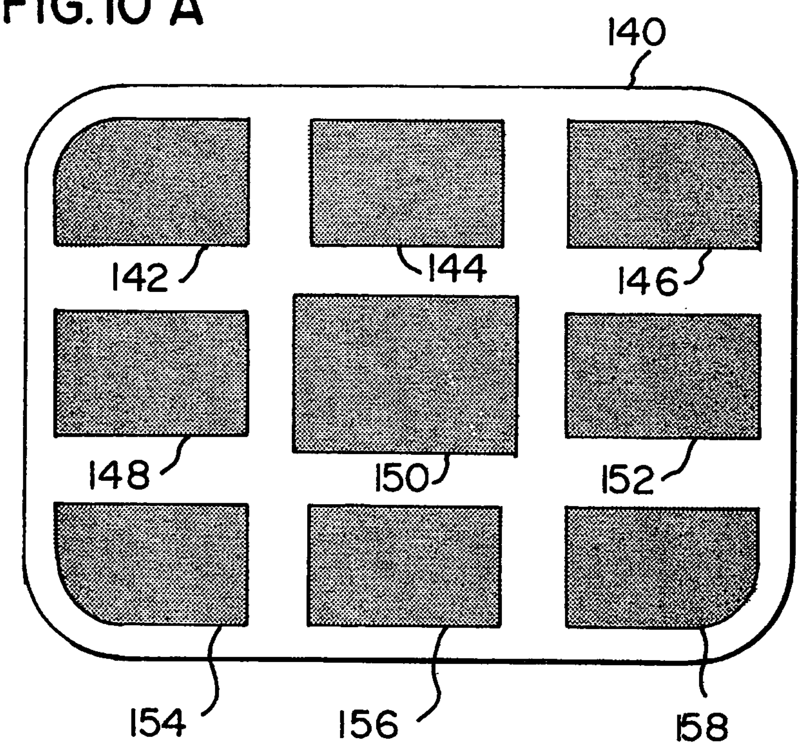

FIG. 10B